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Title:

WATERMARKING DIGITAL IMAGES WITH INTENSITY SPECIFIED BY AREA ;

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ABSTRACT:

The present invention is directed to watermarking an image using the highest practical watermark intensity that can be used without creating visual artifacts. With the present invention, an image is divided into areas. The size and shape of each area are determined so that each area only contains portions of the image where it is appropriate to use a watermark signal having the same energy (A). Some images consist of a series of lines. Such images are often used as the background image on security documents or currency (A). If an image consists of a series of lines, the invention can be applied by dividing the image into areas where the lines that form the image are within a certain range of widths (Tile). An appropriate watermark intensity is then determined for each such area and a watermark of this intensity is applied to the image. If an image is a grayscale image, areas having the same tonal value or tonal density are determined directly, or the image is transformed into a line art image and areas with the same size binary valued areas (lines, dots, squares, etc.) are selected by filtering the image. After the image has been divided areas which have a line width or tonal density value that is within a certain range of values, an appropriate watermark energy level is assigned to each area. The image is watermarked by changing the value of each bit or pixel in the image by an amount determined by both the value a payload tile and the intensity value associated with the area in which the bit or pixel lies.

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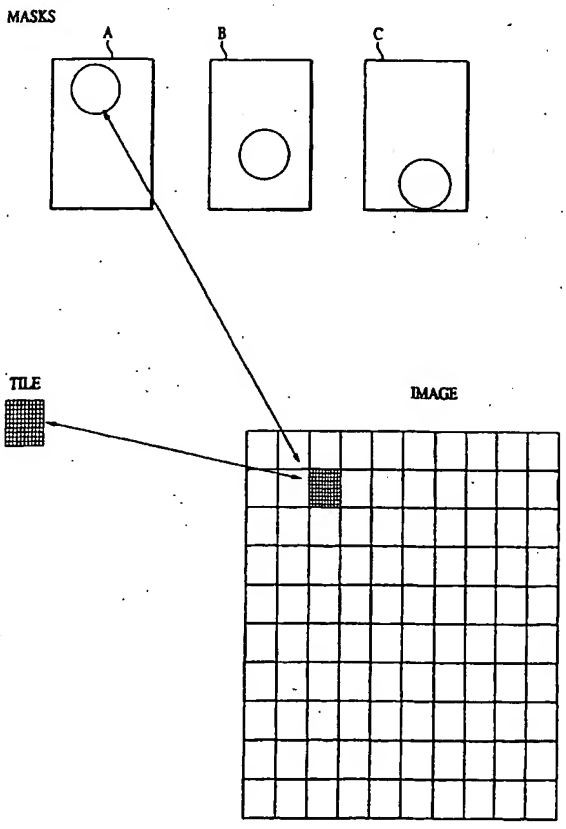
(54) Title: WATERMARKING DIGITAL IMAGES WITH INTENSITY SPECIFIED BY AREA



(57) Abstract: The present invention is directed to watermarking an image using the highest practical watermark intensity that can be used without creating visual artifacts. With the present invention, an image is divided into areas. The size and shape of each area are determined so that each area only contains portions of the image where it is appropriate to use a watermark signal having the same energy (A). Some images consist of a series of lines. Such images are often used as the background image on security documents or currency (A). If an image consists of a series of lines, the invention can be applied by dividing the image into areas where the lines that form the image are within a certain range of widths (Tile). An appropriate watermark intensity is then determined for each such area and a watermark of this intensity is applied to the image. If an image is a grayscale image, areas having the same tonal value or tonal density are determined directly, or the image is transformed into a line art image and areas with the same size binary valued areas (lines, dots, squares, etc.) are selected by filtering the image. After the image has been divided areas which have a line width or tonal density value that is within a certain range of values, an appropriate watermark energy level is assigned to each area. The image is watermarked by changing the value of each bit or pixel in the image by an amount determined by both the value a payload tile and the intensity value associated with the area in which the bit or pixel lies.

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— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

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Watermarking Digital Images With Intensity Specified by Area

Related Application:

The present application is a continuation of application 60/152,520 which was filed 09/01/99.

Field of the Invention:

The present invention relates to steganography and more particularly to techniques for watermarking digital images.

Background and Summary of the Invention:

The technology for watermarking digital images is well developed. The intensity of the watermark determines both if the watermark will create visual artifacts and how easily the watermark will be to detect after an image has been printed, copied or otherwise transformed. When inserting a digital watermarking into an image, it is desirable to utilize a high intensity watermark signal, that is, to change the intensity of the pixels in the image as much as possible so that it will be easy to detect and read the watermark. However, if the intensity of the watermark signal is too high, the watermark may create visual artifacts in the image, that is, the watermark signal may be visually evident.

Many watermarking technique are "perceptually adaptive". Perceptually adaptive watermarking techniques take into account the characteristics of an image in an effort to make a watermark relatively easy to detect and to avoid causing visually apparent artifacts in the watermarked image..

A perceptually adaptive watermarking technique is for example shown in U.S. patent number 5,748,763 entitled "Image Steganography System Featuring Perceptually Adaptive and Globally Scalable Signal Embedding" by Geoffrey B. Rhoads. Certain commercially available image editing programs (such as the image edition program marketed by Adobe Corporation under the trademark "Adobe Photoshop") can watermark digital images using perceptually adaptive techniques.

The present invention is directed to watermarking an image using the highest practical watermark intensity that can be used without creating visual artifacts. With the present invention, an image is divided into areas. Each area only contains portions of the image where it is appropriate to use a watermark signal having the same energy level.

Some images consist of a series of lines. Such images are often used as the background image on security documents or currency. If an image consists of a series of lines, the invention can be applied by dividing the image into areas where the lines that form the image are within a certain range of widths. An appropriate watermark intensity is then determined for each such area and a watermark of this intensity is applied to the image. Watermarks can be applied to such images using the line width modulation techniques shown in co-pending US applications 09/074,034, filed May 6, 1998 which corresponds PCT/US99/08252, and 09/127,503, filed July 31, 1998 which corresponds to PCT/US99/14532.

If an image is a grayscale image, areas having the same tonal value or tonal density are determined directly, or the image is transformed into a line art image and areas with the same size binary valued areas (lines, dots, squares, etc.) are selected by filtering the image.

After the image has been divided areas which have a line width or tonal density value that is within a certain range of values, an appropriate watermark energy level is assigned to each area. The image is watermarked by changing the value of each bit or pixel in the image by an amount determined by both the value in a payload tile and the intensity value associated with the area in which the bit or pixel lies.

The invention is applicable to watermarking techniques which change the value of a binary parameter in areas of an image (for example, by modulating the width of lines in a line image) or to watermarking techniques which change the value of a multi-valued parameter in areas of the image (for example, by changing the luminance value of the pixels in an image).

Brief Description of the Drawings:

Figure 1 shows three areas each of which have lines of different width.
Figure 2 shows an image after a mask has been applied
Figure 3 shows an image divided into a grid.
Figure 4 shows a computer with the programs used to practice the present invention.
Figure 5 is an example of a gray scale image.
Figure 6 is an example of a line art image where the binary elements are lines.
Figure 7 is an example of a line art image where the binary elements are circles.

Description of a preferred embodiment:

In the first preferred embodiment, the invention is applied to a image which consists of a series of lines. Images which consist of a series of line are, for example, often found as a background imagery on security documents and on currency. A digital watermark can be inserted into such an image using line width modulation techniques such as those shown in co-pending US patent applications 09/074,034, filed May 6, 1998 which corresponds PCT/US99/08252, and 09/127,503, filed July 31, 1998 which corresponds to PCT/US99/14532. The disclosures of the above referenced patent applications is incorporated herein in their entireties

A typical image which consists of a series of lines will have a relatively complex set of lines; however for ease of explanation the invention will herein be described as applied to a very simple image. The invention can be applied to complex images in exactly the same was as described herein as applied to a simple image.

Figure 1 shows three areas designated A, B, and C. Each of the areas A, B, and C has lines with a width that differs from the width of the lines in the other areas. The lines in area A are relatively narrow, the lines in area C are relatively wide, and the lines in area B have an intermediate width. Area C can absorb much more watermarking energy than can area A without creating any visual artifacts.

For ease of reference the line width in the three areas (in terms of pixels and resolution) will hereinafter be referred to by line width index numbers as follows:

Area A – 0.5
Area B – 1.0
Area C – 2.0

The actual width of the lines in terms of pitch or pixel width will depend upon the specific application. For example, an index number of 1.0 could for example correlate to a pitch of 2. With respect to the present invention the important factor is the relative width of the lines and this relative width can be most easily represented in a general manner by using index numbers.

Many commercially available image editing programs (such as, for example, Adobe Photoshop) include the ability to make image filters, and masks. For example, using such programs an image can be filtered to eliminate all lines that have (in terms of the

above line width index values) a width of less than 1.0. If such a filter is applied to the image shown in Figure 1, area A would be eliminated, resulting in an image such as that shown in Figure 2 which only has areas B and C. The image in Figure 2 could then be subtracted from the image shown in Figure 1 to produce an image (or mask) that only includes the image in area A . Next the image could be filtered to remove all lines with a line width index of less than 2.0. The result would be an image with only area C. The image with area C could be subtracted from the image with areas B and C to produce an image with only area B. One would thus have three images (or masks) each of which include lines with a particular line width index, that is, each of which specify an area which should be watermarked at a particular intensity.

It is desirable to watermark the three areas in the original image (each of which is defined by a different mask) with the maximum watermark energy without creating visual artifacts. The three masks described above can be used to control the watermarking operation as described below.

As is conventional, in order to achieve reliability the image is divided into a grid as shown in Figure 3. Each square in the grid will be x pixels on each side and thus each square will consist of x^2 pixels. The watermark data is inserted into each of the squares on the grid. The watermark data (termed the payload) is specified by a payload tile. The payload tile defines an amount of change for each pixel in the tile. The size of the tile is the same size as the size of the squares in the grid on the image, that is, in the example given the payload tile will have x^2 pixels. The tile specifies a relative amount of change for each pixel in a square on the image that will result in a particular watermark payload. The value of the changes specified by the payload tile are calculated using watermarking techniques such as those described in the previously referenced patent and patent applications. In prior watermarking techniques the pixels in each square of the grid on the image are changed in accordance with the amounts specified in the payload tile in order to watermark the image.

However, with the present invention, when changing the pixels in the image in accordance with the payload tile, an additional intensity factor is taken into account. For example, in a particular square on the grid, the pixels in the square may only be changed by one half of the amount specified in the payload tile. In another square on the grid. the pixels may be changed by seventy five percent of the amounts specified in the payload tile. That is, a watermark can be inserted into the image by changing each

pixel in the image by an amount specified by an associated pixel in a payload tile, as modified by an intensity factor. The intensity factor for each pixel in the image is specified using the previously described masks which define an appropriate intensity for different areas of the image.

The watermarking operation proceeds as shown in Figure 3. Each pixel in each square of the image is changed by an amount which depends both on the value specified for the corresponding pixel in the payload tile and by an intensity value. The intensity value is determined by looking at a series of masks. Each mask specifies a particular intensity. If the mask has an image at the location of the corresponding pixel, the intensity associated with that mask will control the intensity of the change.

The masks are ordered (with the mask specifying areas with the least intensity first) and if two masks have images at the same location, the first mask in the series controls the intensity of the pixels. The payload tile includes a value for each pixel in a square on the image. Each pixel in each square of the image is changed by an amount that depends both on the value specified by the associated pixel in the payload tile and by the various masks that define areas of the image to be watermarked at various intensities. The intensity that should be associated with a mask for an area having a particular width index can be determined by trial and error. However, once determined this value can be used for subsequent operations. That is, while the shape of the masks for different images will vary according to the characteristics of the image. The intensity value assigned to a mask which represents area having a particular width index can be the same for different images.

A system for performing the above described operations is shown in Figure 4. The system includes a conventional personal computer system 401. This can for example be a Intel Pentium III system operating under the Microsoft Windows operating system. The computer system 401 includes conventional I-O devices such as a display, a keyboard, a printer, etc, conventional storage devices such as RAM, hard drive, CD drive etc. Such conventional components are not shown in Figure 4.

The system includes an image edition program 403 such as for example the Adobe Photoshop image editing program. The image editing program 403 includes a image watermarking facility 405, an image filtering facility 407, and an Image addition and subtraction facility 408. Except for the details described herein, the image editing

program 403, the watermarking facility 405, the filtering facility 407, and the image addition and subtraction facility 408 are standard conventional components.

The embodiment of the invention described above applied a watermark to an image that consisted of a series of lines with different width. The embodiment of the invention described below applies the invention to a half tone image such as that shown in Figure 5. The half tone image shown in Figure 5 is a conventional halftone image. It can for example be a single color channel of a multicolor image.

Halftone images such as image 500 that shown in Figure 5 can be transformed into line art images such line art image 601 shown in Figure 6. This conversion can be done by conventional, well knows processes regularly used in the printing industry. After a half tone image such as image 500 shown in Figure 5 is converted to a line art image such as image 601 shown in Figure 6, the invention can be applied as previously explained with respect to the first embodiment of the invention. That is, image 601 shown in Figure 6 can be divided into areas, each of which has lines the width of which falls in a particular range. This can be done as previously explained by applying line width filters and subtracting from the original image to form a series of masks, each of which define an area with lines whose width fall within a selected or specified range.

After the areas with lines of similar width are defined as described above, the image is watermarked. As in the first embodiment, the intensity at each location in the image is defined by both the payload tile and the masks which define the area having line width in a specified range.

The line art image 601 shown in Figure 6 appears as a series of lines. As is well known in the printing art the elements in a line art image need not be lines. The elements in the line art image can be circles as in image 701 shown in Figure 7. The particular shape of the elements is generally selected for various esthetic reasons and the present invention can be used with elements having any desired shape. The filtering to define areas having the same tonal density would proceed as previously described irrespective of the shape of the elements in the line art image.

It should be understood that the images shown in Figures 5, 6 and 7 are merely representative of gray scale images. The invention can be applied to gray scale images developed with any of the processes known in the printing industry.

Digital images consist of an array of bits or pixels. With the present invention, the bits or pixels in an image are divided in two ways. First the bits or pixels of an image are divided into arrays the size of a watermark payload tile as is conventional. Second the pixels of the image are divided into what can be termed secondary control areas.

The first division of the pixels or bits is into areas that are identical in size. That is, the first division divides the pixels into areas each of which is the size of the payload tile. The payload tile specifies the change in each bit or pixel in an area the size of said payload tile. The amount specified by the values in said payload tile is the amount which is appropriate for the watermark to carry the desired payload data. The values in the payload tile can be established and used on a perceptually adaptive basis

The secondary control areas are not necessarily identical in size. Furthermore, the size of the secondary control areas is not related to the size of the watermark tile. The secondary control areas are areas of the image which have some particular characteristic. For example they are areas of the image which have lines within a specified width range or areas which have tonal density values within a specified range.

Each secondary control area has an associated control value. For example the control value associated with each secondary control area can be the intensity of the watermark which is appropriate for the particular area.

The embodiments described herein give specific and novel techniques for dividing an image into secondary control areas. It should however, be understood that various other and different techniques can be utilized to define secondary control area for a document.

While the invention has been described above with respect to various embodiments, it will be appreciated by those skilled in the art that that the scope of the invention exceeds the specific embodiments described herein. Various other changes in form and detail can be made without departing from the sprit and scope of the invention.

The scope of applicant's invention is limited only by the appended claims.

I claim:

1) The method of watermarking a digital image to embed a watermark specified by a watermark multi-bit payload tile, said image formed by an array of bits, said array of bits covering a plurality of payload tile sized areas, said method comprising the steps of dividing said image into secondary control areas, each secondary control area covering a portion of said image where a characteristic of said image falls within a particular range, each secondary control area having an associated secondary control value, changing the value of the bits in each payload tile sized area of said image based upon both the value of the corresponding bit in said payload tile and the value of the secondary control value associated with the secondary control area in which the bit resides.

2) The method recited in claim 10 wherein said characteristic of said image is the width of lines in said image.

3) The method recited in claim 10 wherein said secondary control value is the intensity of said watermark.

4) A system for watermarking a line art image comprising
means for determining areas of said image having lines within specific size ranges,
means for applying a watermark to said image, the intensity of said watermark in each area being established at a selected value.

5) the system recited in claim 4 wherein said watermarking means applies a watermark by modulating the size of said lines.

6) The system in claim 4 wherein said means for determining utilizes filtering.

7) A method of applying a digital watermark to an image comprising the steps of
dividing said image into areas each of which have a tonal value within a pre-established range, each range being able to carry a watermark of a particular intensity without creating a visual artifact,
applying a digital watermark to said image, the intensity of said digital watermark in each area being set to the particular intensity associated with said area.

8) A method of watermarking a half tone mage comprising the steps of converting said half tone image into a line art image, filtering said line art image to create a series of masks defining areas of said half tone image having tonal density within a specified range, each range of tonal densities having an appropriate watermark intensity, watermarking said halftone image, the intensity of the watermark in each area being set to said appropriate intensity.

9) The method of watermarking a digital line art image comprising the steps of determining areas of said image having lines within specified size ranges, generating a watermark tile which will carry watermark data, applying a digital watermark to said image in multiple areas each of which is the size of said watermark tile, the intensity of said digital watermark in each area being established at a value determined by said watermark tile and said. said watermark.

10) The method of watermarking a line art image comprising the steps of determining areas of said image having lines within specified size ranges, applying a digital watermark to said image, the intensity of said digital watermark in each area being established at a selected value.

11) The method recited in claim 10 wherein said watermark is applied by modulating the width of said lines.

12) The method recited in claim 10 wherein said determining step is performed by filtering said image.

13) The method recited in claim 1 wherein said image is a line art image and said characteristic of said image is the size of the lines in said image.

14) The method recited in claim 1 herein said characteristic is the tone of said image.

15) The method recited in claim 1 wherein said image consists of a series of lines and wherein said characteristic is the width of said lines, and wherein said secondary control value is the intensity of said watermark.

16) The method recited in claim 15 wherein said image is watermarked by line width modulation.

17) A system for watermarking a digital image to embed a watermark specified by a watermark multi-bit payload tile, said image formed by an array of bits, said array of bits covering a plurality of payload tile sized areas, said system including means for dividing said image into secondary control areas, each secondary control area covering a portion of said image where a characteristic of said image falls within a particular range, each secondary control area having an associated secondary control value, and means for changing the value of the bits in each payload tile sized area of said image based upon both the value of the corresponding bit in said payload tile and the value of the secondary control value associated with the secondary control area in which the bit resides.

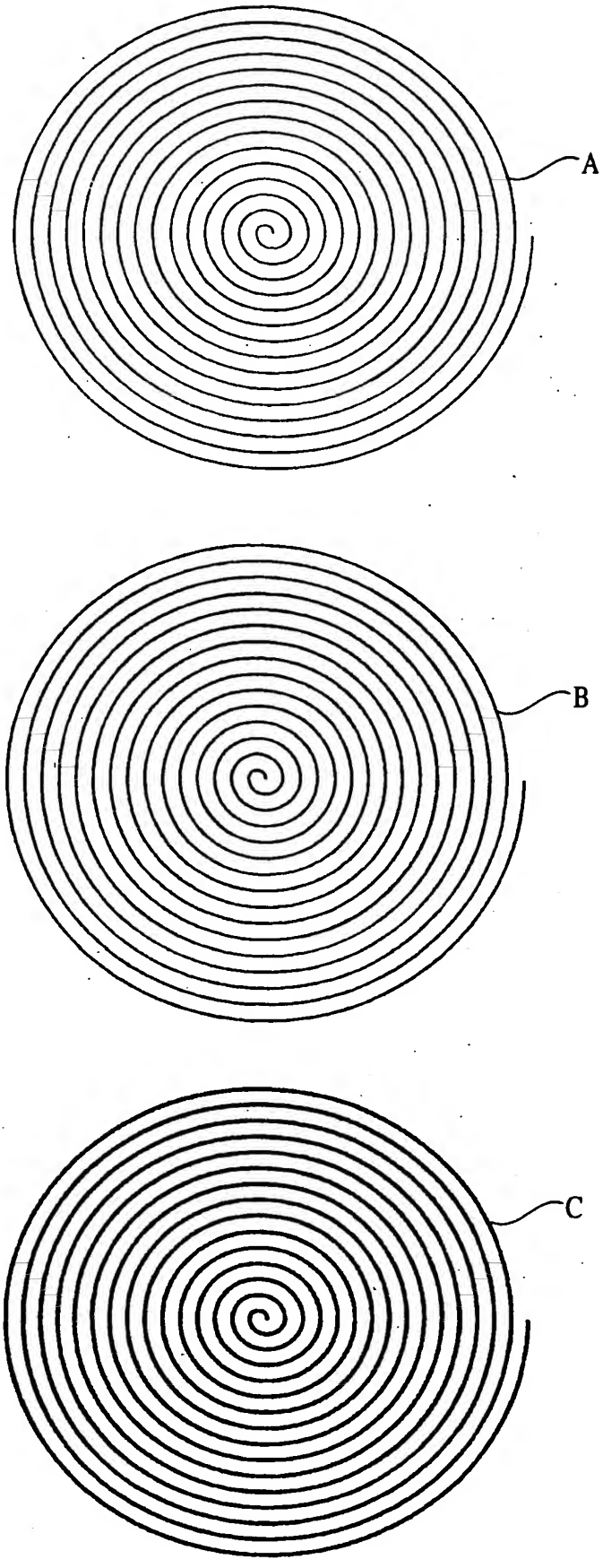

FIG. 1

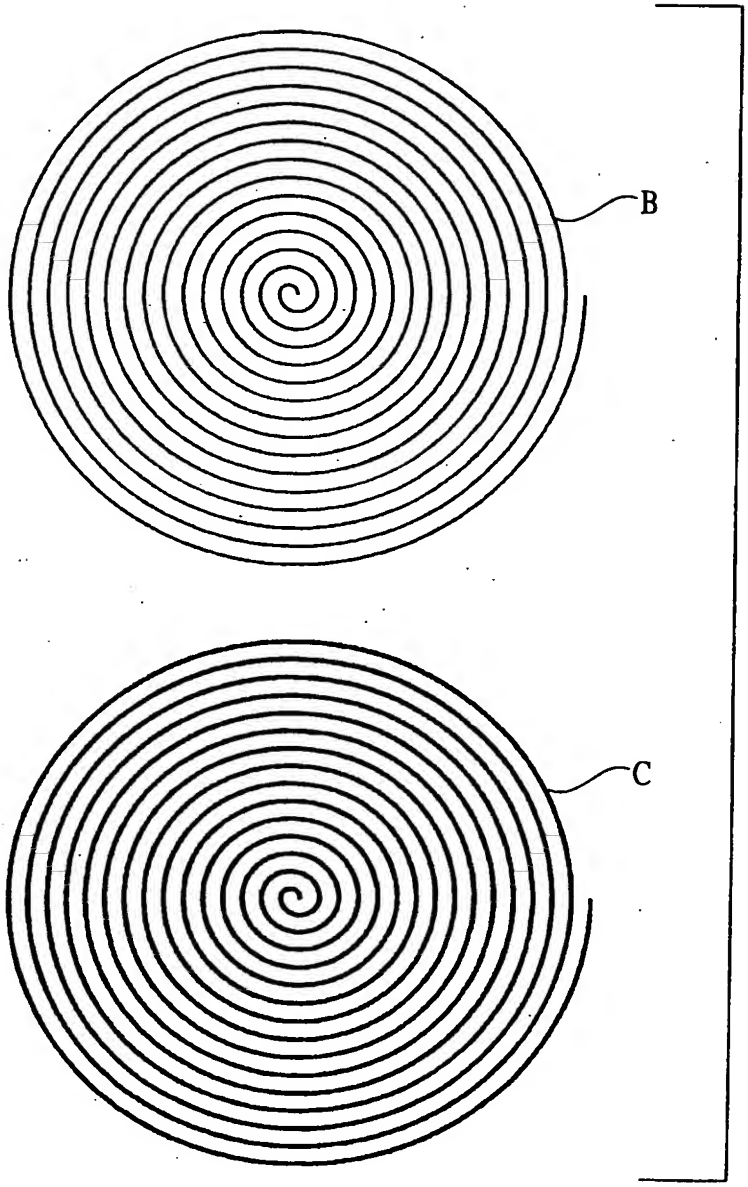

FIG. 2

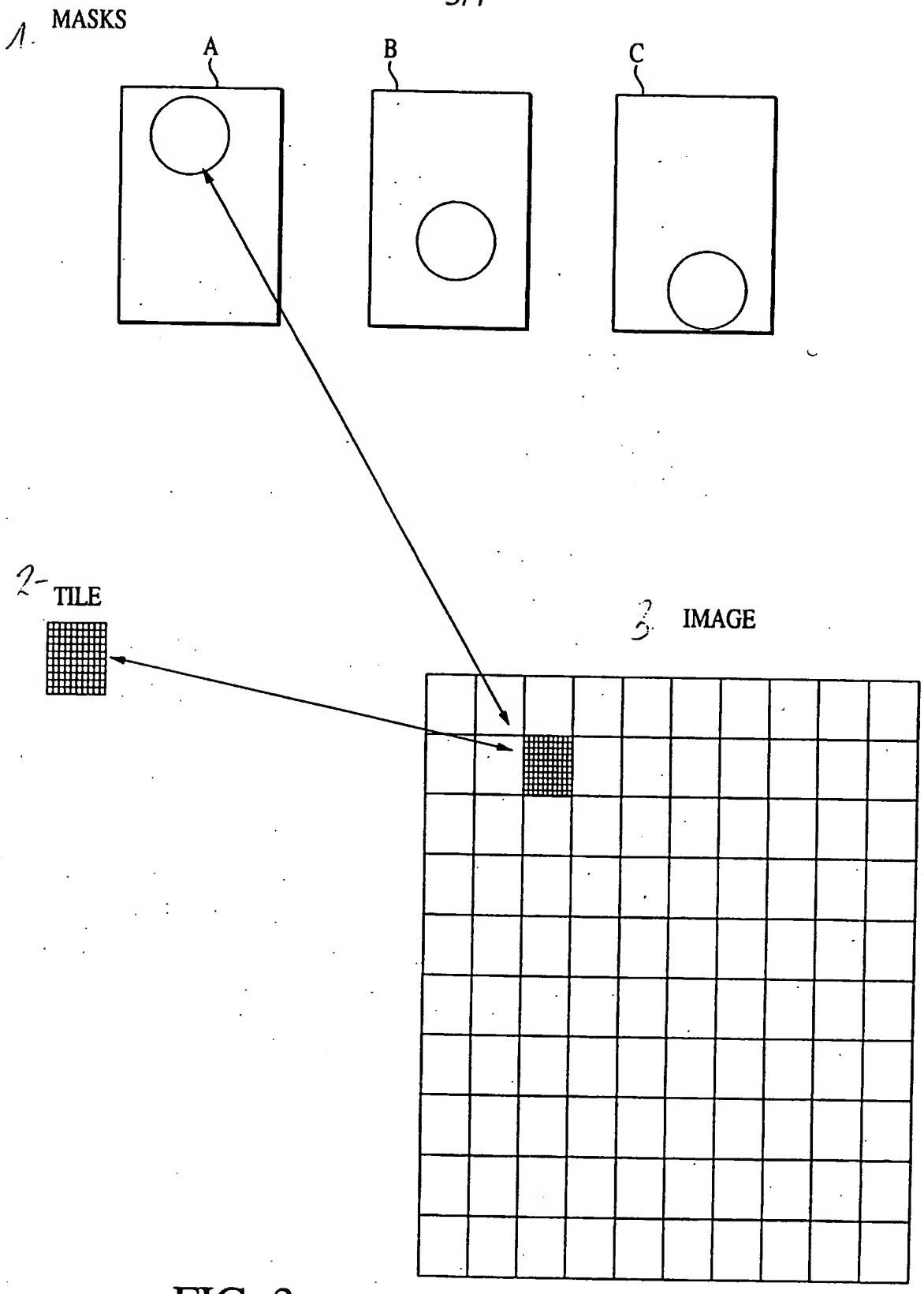

FIG. 3

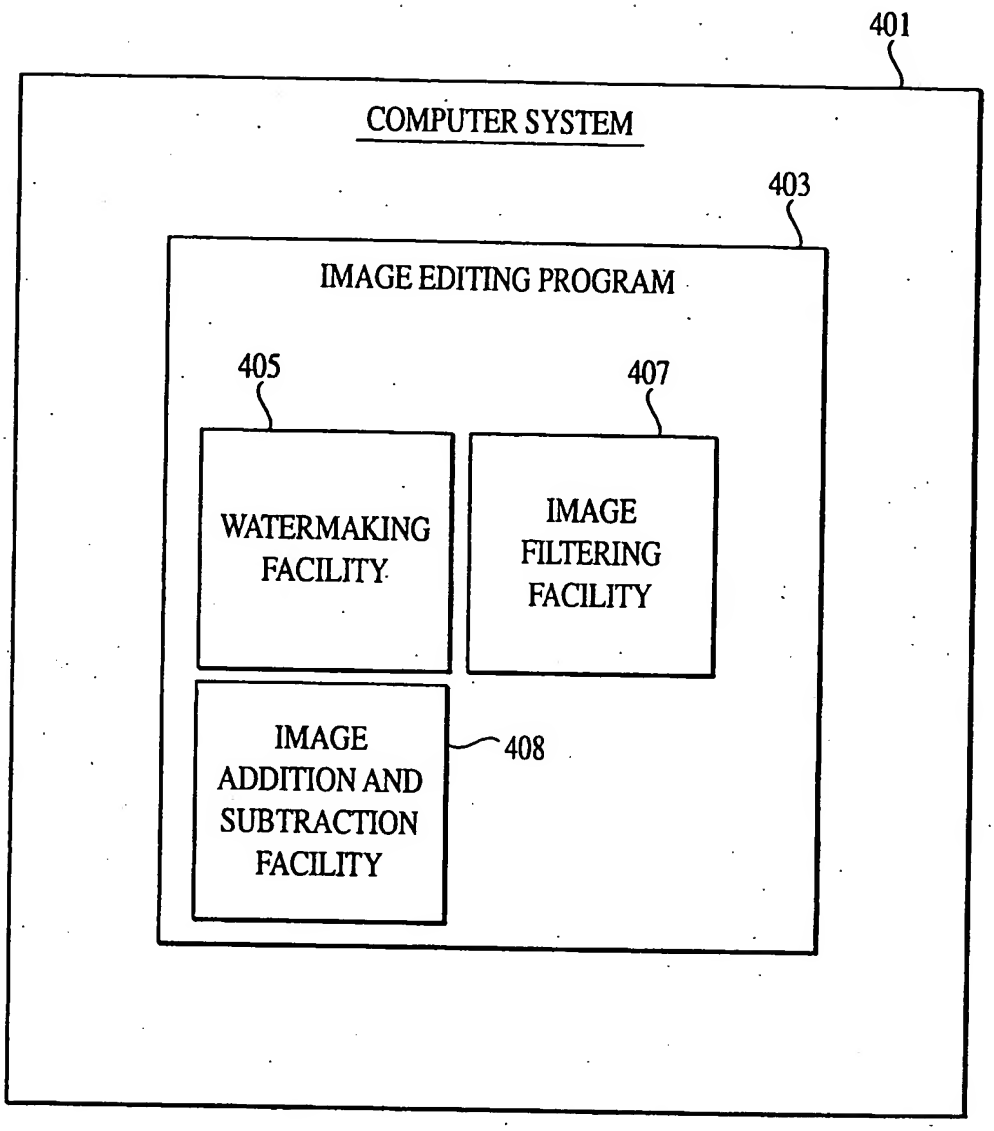
401
COMPUTER SYSTEM
403
IMAGE EDITING PROGRAM
405
407
WATERMAKING FACILITY
IMAGE FILTERING FACILITY
IMAGE ADDITION AND SUBTRACTION FACILITY
408

FIG. 4

FIG. 5

FIG. 6

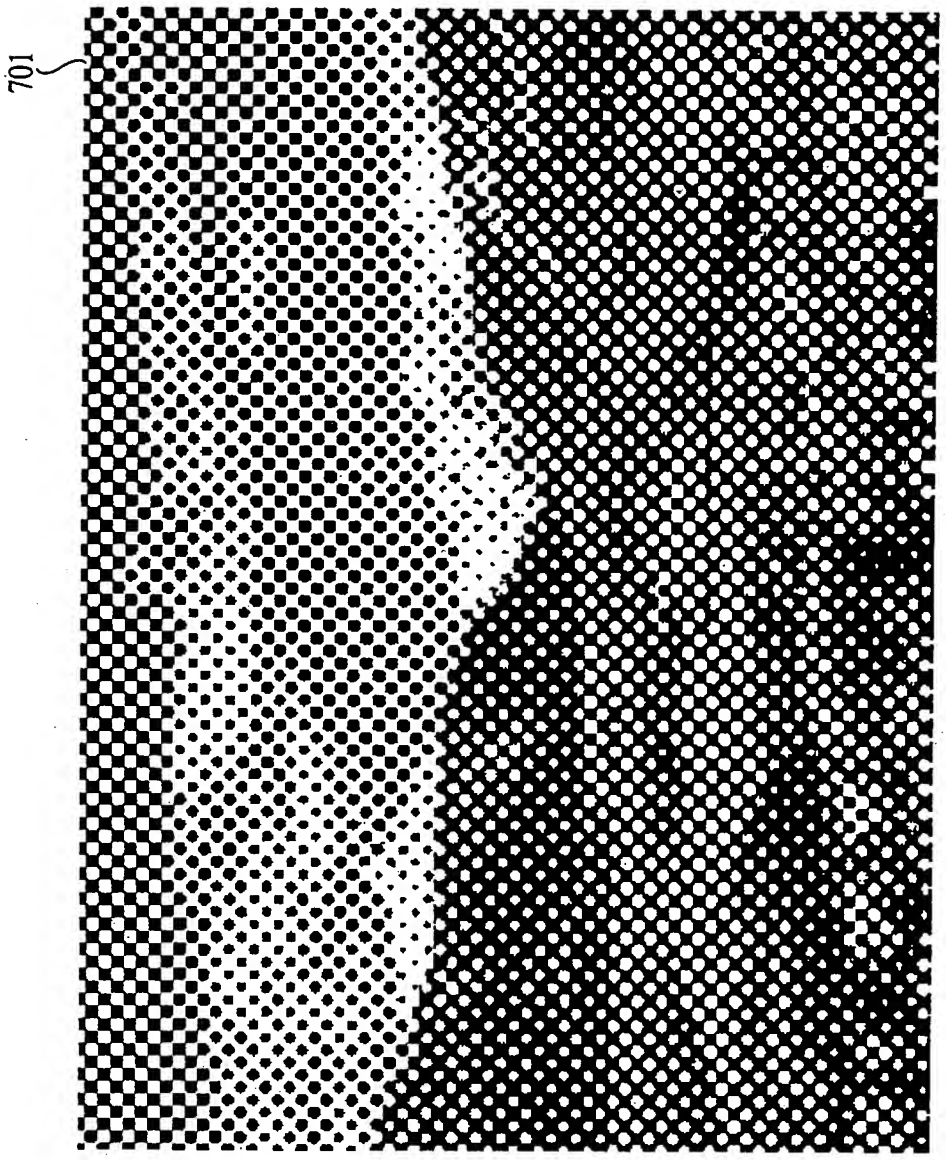

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/23643

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G06K 9/00, G06K 9/36
US CL :382/100,232

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 382/100, 232

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,946,103 A (CURRY) 31 AUGUST 1999, col. 9, line 42 through col. 10, line42.	1-17
A	US 5,528,740 A (HILL et al.) 18 JUNE 1996, col. 10, lines 20-52.	1-17
A	US 4,649,435 A (KRAMER) 10 MARCH 1987, col. 9, line 24 through col. 10, line 19.	1-17

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*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search 10 NOVEMBER 2000	Date of mailing of the international search report 29 DEC 2000
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